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Adaptation of Electrical Engineering Education to the COVID-19 Situation: Method and Results

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***Abstract*—In this paper are presented a new extended methodology and tools for providing electrical engineering education in a distant form. It was used by two Bulgarian universities, in order to adapt their Electrical engineering classes to the COVID-19 situation. The methodology includes several phases: needs analysis, preparation of educational materials, selection of teaching methods, increasing competencies and selection of assessment methods. In the results of the paper is presented the implementation of the methodology based on the EVEEE environment for electrical engineering equipment. At the end of the semester a questionnaire was conducted among the students. The results about the students' opinion clearly indicate that engineering education should be implemented in a distant form only during emergency situations.**

Keywords—electrical engineering, distant education, virtual lab, COVID-19

I. Introduction

In March 2020 Bulgaria officially entered emergency situation aimed at preventing the spread of the COVID-19 virus. As a result, all non-critical spheres of the economy were either closed or certain restrictions were implemented, mainly aimed at isolation. Therefore, all educational institutions in Bulgaria were forced to switch to distant forms of education. The implementation of distant education has several aspects – preparation of the teachers, of the administrative staff and of the students. This study is mainly focused on the first group.

Engineering education relies on several learning activities – lectures, tutorials, practical and laboratory exercises [2]. The possibilities for implementing distant lab exercises are generally limited to circuit simulation software, such as SPICE, Multisim, Microcap, etc. and virtual and remote laboratories [3]. Numerous approaches exist, which allow virtual electrical engineering education at different levels of abstraction. They vary from simplified 2D labs [8] to realistic 3D virtual reality [9]. National instruments have developed a combination of hardware and software tools, which allow the remote control of virtual equipment [10]. Other well-known virtual laboratories are supported by Masachusets Institute of Technology (iLab) [11], Tecnológico de Monterrey University (eLab) [12], the VISIR project [13], and many others.

According to [1], the quality of distant education is ensured with several steps during its implementation: needs analysis, guidelines and implementation for preparing instructional materials, ensuring learning and practical experience for the teachers and following the syllabus. Numerous studies were aimed at improving the quality during distant forms of education. In the ROLE project [4], the goal was to use web technologies in order to provide personalized and adaptive learning environment. In another study, a dashboard was integrated into an online learning system [5]. Furthermore, a tool was developed that guides students in their work, traces their search for reference materials on the web and tracks their interaction with the system.

Another important factors in distant education are the potential cybersecurity problems and the cybersecurity expertise of the participants [6,7]. This aspect concerns both teachers and student and should be taken care of during design time.

This study presents a methodology and results from the implementation of distant education during the spring of 2020 as part of the Electrical engineering courses in two Bulgarian universities – University of Ruse Angel Kanchev (URAK) and University of Mining and Geology "St. Ivan Rilski" (UMG). It concerns a wide range of problems, aimed at ensuring the necessary quality of education.

II. Materials and Methods

In this section is described the methodology used for preparation of the educational process for distant learning.

A. Needs analysis

The courses that are object of this study are "Electrical engineering" and "Electric measurements". The first was toughed to electrical and computer engineering students in URAK and non-electrical engineering students in UMG. The second course was taught to electrical engineering students in UMG. According to their syllabuses, the courses require the use of lectures, laboratory and tutorial exercises. The laboratory exercises are a fundamental requirement for these courses as during them the students acquire practical knowledge and experience on working with electrical equipment.

In the period 2018-2019, a team from RUAK developed the so-called Engine for Virtual Electrical Engineering Equipment (EVEEE), which is a 2D virtual laboratory, which represents a 3D virtual reality. Therefore, this tool was selected for the implementation of the laboratory exercises, i.e. a shared infrastructure was used by both URAK and UMG students.

B. Development of training materials

Next, several types of educational materials have to be developed, in order to meet the requirements of the target courses syllabus. This includes preparation of:

1. New virtual laboratory exercises, corresponding to the course syllabus;
2. Guidelines for implementation of the virtual labs;
3. Electronic reports, where the student can fill in and summarize the results from their virtual experiments.

Initially, the necessary laboratory exercises have to be identified and selected. However, this should be done in accordance with the available virtual equipment, supported by the EVEEE environment. Once the topics are selected and the necessary equipment is identified, the virtual lab is created using the engine's system for automated design of labs.

Next, methodological instructions are developed for each virtual lab. They could vary in a wide range, such as pdf files (text + screenshots), PowerPoint presentations and recorded video instructions.

In traditional education, students are commonly required to summarize the experimental results in a report. Furthermore, they often require the help of their tutors to summarize the lab results in graphical form and to proceed with further analysis. In a distant form of education, such help would be hard to implement, therefore a different approach is selected. For each virtual lab an electronic report should be developed, which can provide the necessary guidelines, including graphical representation of the experimental results.

C. Choosing the educational methods

Considering the wide variety of specialties, involved in this study, the level of students' IT competence were significantly different. This means that if the students spend too much time on understanding how to work with the virtual tools, this would prevent them from understanding the idea behind the labs and the electrical engineering basics. According to [14], in order to provide gradual progress in the educational process, it is necessary to provide step-by-step instructions during the preparation, implementation and reporting phases. According to the principles of segmentation and adaptation [15], in this case either synchronous introductory virtual laboratory exercise or asynchronous recorded video instructions are extremely necessary. With the help of these tools, teachers demonstrate how to work with the virtual environment. Therefore, the following educational methods should be considered, in order to provide the necessary teaching quality:

1. Sharing materials, such as recorded video instructions, pdf files, etc., using e-Learning websites;
2. Synchronous communication based on video conferencing, including presentations, screen sharing (by both teacher and student), etc.;
3. Asynchronous communication using e-mail.

D. Increasing competencies

According to Bloom's taxonomy [16], the development of competencies is divided into two sub-stages, the first covering the skills of analysis and the second including the skills of synthesis and evaluation. In order to increase the competencies of the students, discussions should be held at the same time to improve the competencies in the chat rooms. The synthesis and assessment skills of advanced students have to be enhanced by executing complex tasks, which is demonstrated to the others using screen sharing.

E. Assessment of the results

To assess the real level of progress of students and the correct segmentation of the material [15] it is necessary to introduce another step in the methodology used so far - assessment of the result. The assessment of the education results has two aspects: the obtained knowledge by the students and the efficiency of the educational process.

The assessment of the acquired knowledge by the students could be implemented in several forms:

1. Assessment of the electronic reports of each student;
2. Discussion of the obtained results.

The first approach could be implemented by assigning points to each section of the report, which take part in the forming of the final mark of the course. The second one could be implemented in synchronous form through a video conference session. The discussion could also be achieved asynchronously, using appropriate questions at the end of each laboratory exercise, which the students should answer in their reports.

Finally, in order to assess the efficacy of the provided distant education, a short survey is prepared (Table 1).

A summary of the described methodology in this section is presented using a Use-case diagram (Fig. 1). The role of the Professor is to provide the educational process with the necessary materials and means. The preparation of the labs includes creating the necessary virtual labs, instructions for them and templates for the lab reports. Different forms of instructions are used, such as e-Learning websites, instructions in text form, recorded video instructions. Furthermore, synchronous and asynchronous instructions were provided using video conferencing and messengers/e-mail communication. In order to learn the course material, the Student actor has to execute the

TABLE I. QUESTIONS AND ANSWERS OF THE SHORT SURVEY.

Question	Answers
Which from of laboratory exercises do you prefer - virtual or real?	- I prefer real labs - I have no preferences - I prefer virtual labs
Which of the two forms is more interesting for you?	- Real labs - There is no difference - Virtual labs
Which of the two forms is easier to execute?	- Real labs - There is no difference - Virtual labs
Which of the two forms has higher impact on your education?	- Real labs - There is no difference - Virtual labs

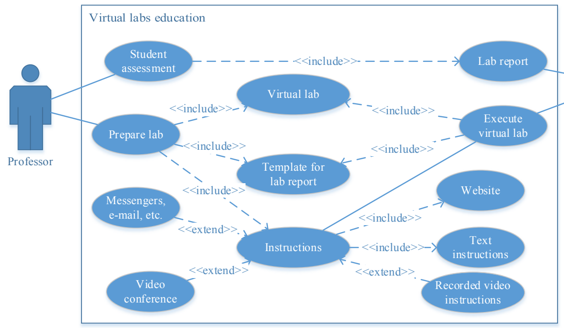

Fig. 1. Use-Case diagram of the adopted methodology

virtual labs by following the instructions and to summarize their results in reports, which are assessed by the Professor.

III. RESULTS AND DISCUSSION

A. Implementation of the methodology

Following the developed methodology, a list of virtual laboratory exercises has been selected, which can be implemented in the EVEEE environment (Table 2).

An example from the virtual lab for investigation of series resonance is presented in Fig. 2. It includes a function generator, a multimeter, a breadboard and three passive elements – resistor, capacitor and inductor. In the other laboratory exercises are also used AC power source, DC power source, power meter, a "black box" two-port device and others devices used in real laboratories.

Next, for each lab were developed implementation guidelines, which have the form presented in Fig. 3. They were structure into "steps" for easier implementation by the students according to segmentation e-learning.

The final stage from the preparation of the learning materials was the development of electronic report templates for each lab. This was achieved online using Google Docs and more precisely Google Sheets. An example report is presented in Fig. 4. According to the developed guidelines were structured the

TABLE II. LIST OF THE SELECTED VIRTUAL LABS

Topic	Course
Investigation of Kirchhoff's laws	EE
Investigation of nonlinear elements in DC circuits	EE
Investigation of series RLC in sinusoidal steady state	EE
Investigation of series resonance	EE
Obtaining the parameters of a two-prot network	EE
Measurement of electric resistance	EM
Measurement of the power factor	EM
Investigation of Thevenin's equivalent circuit	EM
Measurement of electric capacitance	EM

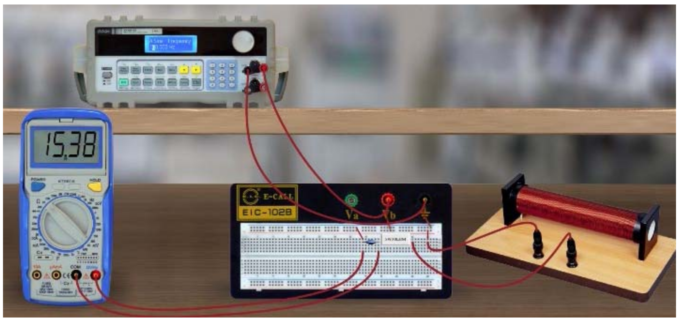

Fig. 2. A virtual lab for investigation of series resonance

Task 1. Investigate the series resonance for the circuit in Fig. 3, using the following elements: $C = 8{,}4\ \mu F$, $L = 300\ mH$ and $R = 30\ \Omega$.

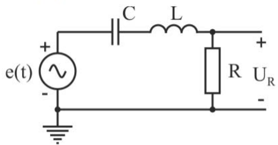

Fig. 3. Circuit schematics for Task 1

Step 1. Connect the circuit from Fig. 3 on the breadboard. Power it from the function generator with input voltage $E = 20\ Vpp$.

Step 2. For each of the frequencies in the report do:

- Set up the frequency from the function generator;
- Measure the RMS value of the voltage on the inductor U_L;

Fig. 3. A fragment from the guidelines for implementing the series resonance virtual lab

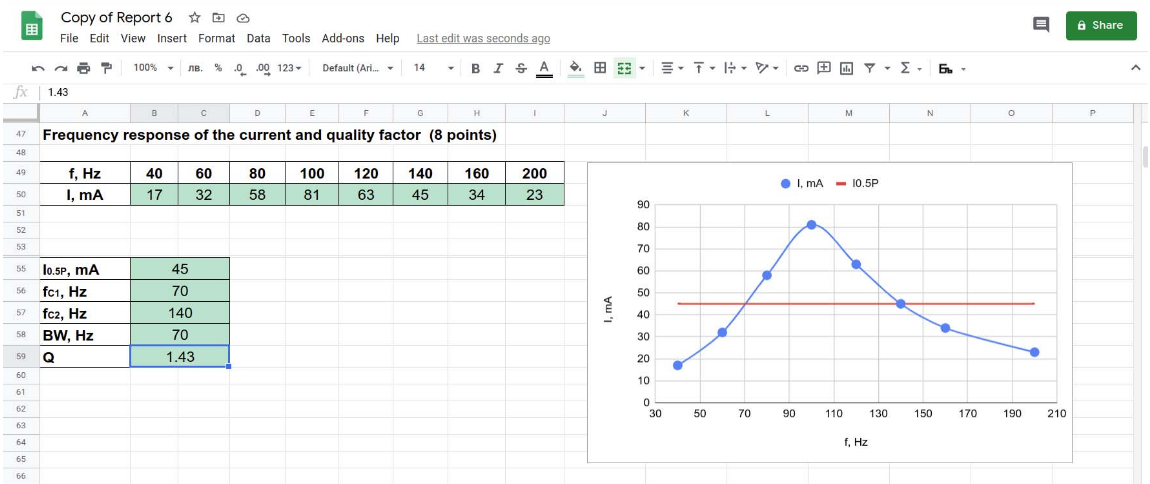

Fig. 4. A lab report implemented in Google Docs

necessary tables. Furthermore, charts were pre-created for automatic visualization of the necessary results when the table data is filled in. This was necessary because the tutor do not have the opportunity to provide online help with the drawing of the graphs. From Fig. 4 can also be noticed that the different sections of the lab report are assigned points, which are later used in the assessment process.

The links to the templates were shared with the students allowing them to make a personal copy of each document. The only disadvantage to this approach is that each student should have a Google account.

Next, the developed materials were shared with the students using e-learning websites. A screenshot from the URAK's e-Learning Shell is presented in Fig. 5. On the presented page are available all materials, necessary for the implementation of one of the labs:

- Instructions in PDF format;
- Recorded video instructions;
- Link to the virtual lab;
- Link to the electronic report and instructions for working with it.

Additionally, synchronous and asynchronous form of communication with the students were used in order to provide them with the necessary instructions during the implementation of the virtual labs.

The discussion with the students was implemented in two ways – synchronously, using online video conferencing and asynchronously, by providing guiding questions, which should be answered in the summary of the reports. For example, the questions at the end of the "Series resonance" lab are presented in Table 3.

B. Results from the performed survey

In order to improve and adapt the training process, at the end of the semester all students were asked to fill in a short anonymous questionnaire. It was aimed at obtaining their opinion on learning electrical engineering classes in a distant form. The obtained results are presented in Fig. 6-9. A dominating majority of the participants stated that "they prefer real labs", "real labs are more interesting" and "real labs have higher impact on their education". Therefore, we can make the conclusion that students are fully aware that virtual experiments cannot be a full substitute for real experiments.

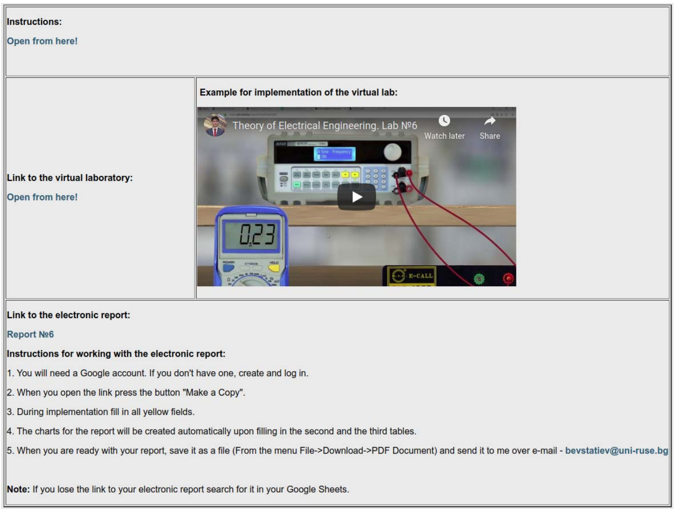

Fig. 5. Screenshot from the E-Learning Shell website of the University of Ruse, providing instructions (in PDF and video format) and links to the virtual lab and electronic report

TABLE III. DISCUSSION QUESTIONS FROM THE LAB FOR INVESTIGATION OF SERIES RESONANCE.

№	Question
1	What are the voltage drops on the inductor and the capacitor during series resonance?
2	What is the reactance of the inductor and capacitor during series resonance?
3	What is the current in the circuit during series resonance?

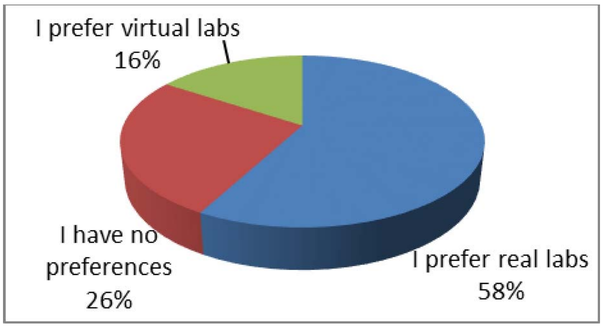

Fig. 6. Answers to the quesiton "Which form of laboratory exercises do you prefer?"

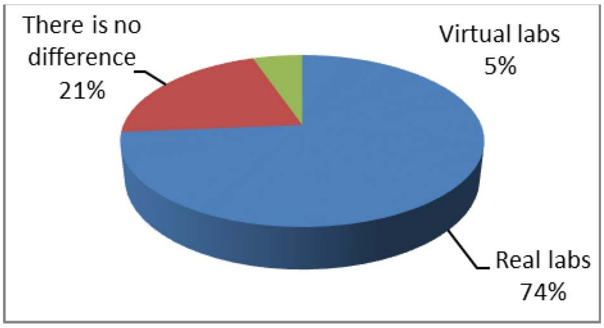

Fig. 7. Answers to the question "Which of the two forms is more interesting for you?"

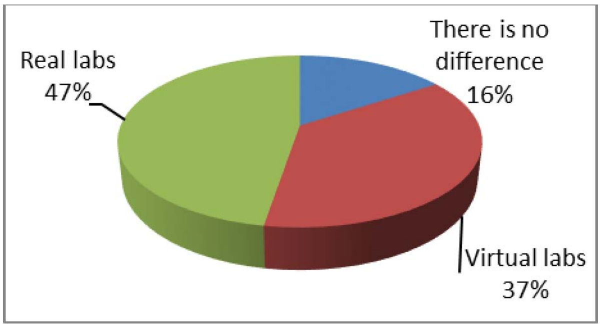

Fig. 8. Answers to the question "Which of the two forms is easier to execute?"

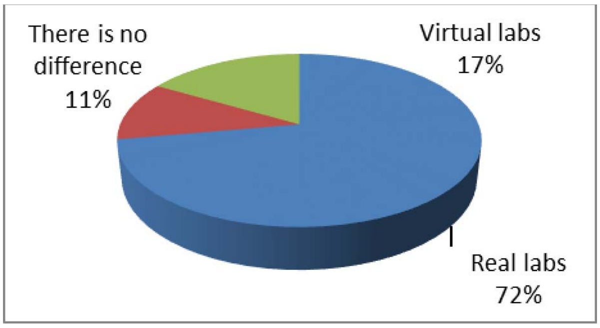

Fig. 9. Answers to the question "Which of the two froms has higher impact on your education?"

The only question in which the votes were divided relatively equally was "Which of the two forms is easier to execute" (47% and 37%, respectively for real and virtual labs). This is probably caused by the difference in the expertise of students on using virtual technologies and the combination of asynchronous and synchronous forms of teaching.

Determining appropriate forms of teaching and methods for adapting the training process will be the next goal of the team.

IV. Conclusions

This study presents the implementation of distant education in Electrical engineering courses during the summer semester of 2020 for two Bulgarian universities – University of Ruse Angel Kanchev and University of Mining and Geology "St. Ivan Rilski". The students involved were from electrical and non-electrical engineering specialties, studying "Electrical engineering" and "Electrical measurements".

Initially a methodology was presented, which includes the following phases: needs analysis, aimed at identifying the key requirements of the education; learning material development; selection of teaching methods; increasing competencies; assessing students and assessing the education methodology.

Next, the required virtual labs were selected and implemented in the EVEEE environment. For each one was also created methodological instructions and templates of electronic reports. All materials were shared with the students using different e-Learning websites. Both synchronous and asynchronous forms of communication were used to implement the communication with the student. This was achieved with the use of video conferencing, screen sharing, preparation of recorded video instructions, e-mail communication, etc.

At the end of the semester a short survey was perform amongst the students in order to assess their attitude towards distant education in electrical engineering courses. The results were predominantly in favor of real labs. Approximately 70% of the student stated that they prefer real labs, and that real labs are more important for their future. This allows us to make the conclusion that students are quite aware of what is important for them and pure distant education should only be used during emergencies, such as the COVID-19 lockdown in 2020.

Virtual laboratories are suitable when it is necessary to refresh knowledge or in preparation for tests. Therefore, they give opportunities for testing and experimenting. In our opinion, the virtual laboratories can be established as an accompanying training in technical specialties but not as a substitution for real practical training.

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